

## Research Article

Julia Menne and Mirco Brunner\*

# Transition from Swifterbant to Funnelbeaker: A Bayesian Chronological Model

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**Abstract:** The transition from the late Swifterbant culture to the first appearance of the Funnelbeaker Westgroup raises numerous questions, from cultural discontinuities to gradual transitions. This process describes the transformation from a late mesolithic of hunter-gatherer societies to a fully neolithic society in Northwestern Europe. The Early Neolithic in this area marks a technological and sociocultural transition zone, which we can identify. Although the first megalithic buildings of the Funnelbeaker Culture were erected around 3600 BC, Swifterbant sites and findings can still be traced. Many studies assume a hiatus between these phases, which is based on a research-historical but also a conservation-related problem. With this contribution, we attempt to generate a chronological Bayesian model on the basis of absolute chronological data. The aim is to compare the numerous available radiocarbon data from different periods in one overview. It is a model to visualize discontinuities or overlaps of the currently available data. It becomes apparent that there is a slide overlap between the archaeologically defined chronological phases. This model serves as a basis for further discussion and chronological models.

**Keywords:** Neolithic, Swifterbant, Funnelbeaker radiocarbon dating, Bayesian method

## 1 Introduction

This study focuses on the geographical area of northwestern Germany, north and northeast Netherlands. This area is defined as a part of the North European plain and characterized by coversands and wetlands. Chronologically, the study centers on the period between 6000 and 2600 cal BC, including the Mesolithic up to the Neolithic. The focus is on the period of Swifterbant and Funnelbeaker Westgroup (TRB) (Figure 1) (Bakker, 1979; Brindley, 1986; Midgley, 1992).

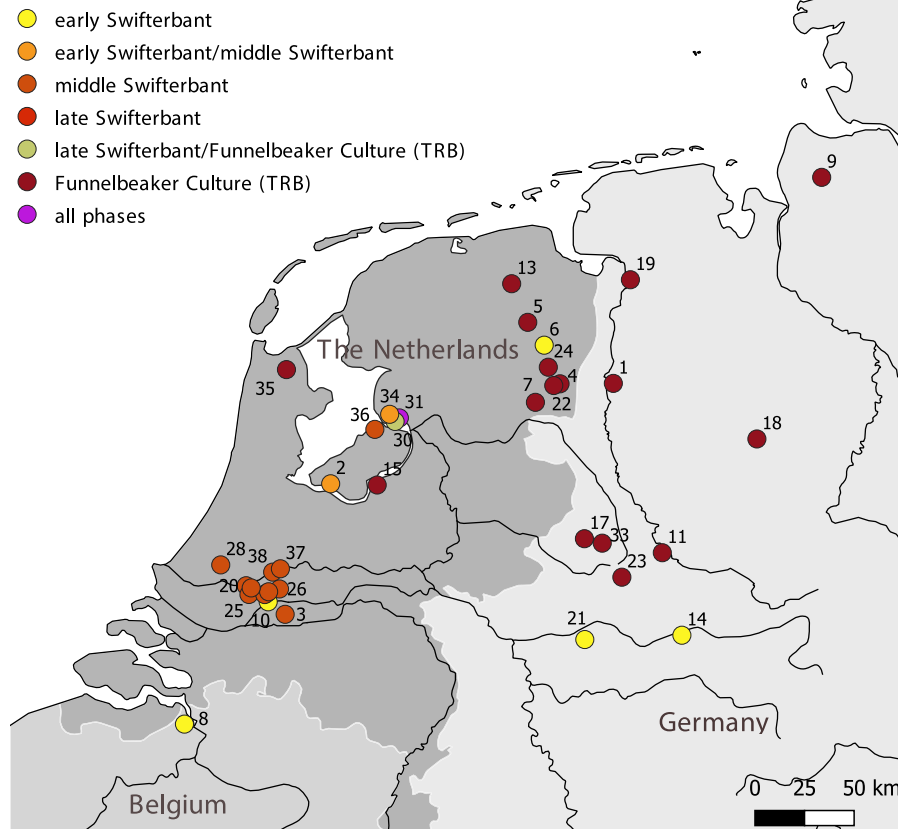
The transition from the late Swifterbant culture to the first appearance of the Funnelbeaker Westgroup in the eastern Netherlands and the western part of Lower Saxony to the northern Westphalia raises chronological questions. They range from the hypothesis of cultural discontinuities to gradual transitions. We thus cover a transition from a late Mesolithic of hunter-gatherer societies to a completely Neolithic society in northwestern Europe. In the study area, it occurs with a delay to Central and Southern Germany and can be understood here as Early Neolithic. In general, the Early Neolithic marks a technological, economic, and socio-cultural transition zone that we can assume to be around 4000–3500 BC. Parts of Neolithic cultural elements are present but still

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\* **Corresponding author: Mirco Brunner**, Kiel University, Institute for Ecosystem Research, Olshausenstrasse 75, 24118 Kiel, Germany, e-mail: mbrunner@ecology.uni-kiel.de

**Julia Menne:** University Hamburg, Institut für Vor-und Frühgeschichtliche Archäologie, Edmund-Siemers-Allee 1, 20146 Hamburg, Germany, e-mail: julia.menne@uni-hamburg.de

## Sites / Phases



**Figure 1:** Specified sites of the Swifterbant culture and Funnelbeaker Westgroup in the study area of the Netherlands and Northwest Germany. Sites: (1) Emmeln 2, (2). Almere-Hoge Vaart, (3) Almkerk, (4) Emmen-Angelslo, (5) Anloo, (6) Bronneger, (7) Dalen-Huidsbergveld, (8) Doel-Deurganckdok, (9) Flögeln, (10) The Harinxveld sites: Giessendam, Polderweg, de Bruin, (11) Gittrup, (12) Glimmen Glimmer Es, (13) Groningen Wischoterdiep, (14) Hamm, (15) Harderwijk, (16) Hazendonk, (17) The Heek sites: Ammerter Mark, Averbek, (18) Hunte 1, (19) Leer-Westhammrich, (20) Lekkerkerk, (21) Marl-Sickmühle, (22) Noordbarge, (23) Nottuln, (24) Odoorn-D32, (25) Oud Alblas, (26) Polder Over-Slingeland, (27) Rommertsdonk, (28) Rotterdam-Berschenhoek, (29) Schaikse Donk, (30) Schokkerhaven, (31) Schokland, (32) Schoonenburgse Heuvel, (33) Schöppingen-Haidberg, (34) Nagele J112, (35) Slootdorp-Kreukelhof, (36) The Swifterbant sites: S1, S2, S3, S5, S6, (37) Zijdeweg 2, and (38) Zevender Hoogte.

crossed by Mesolithic elements. Although the first megalithic buildings of the Funnelbeaker Culture were erected around 3600/3500 BC, a co-existence of Swifterbant sites can still be verified (Paulsson, 2019).

At this point, only the long history of research on neolithization in North Central Europe is mentioned, which can be described correctly as “mosaic” between rather conservative subpopulation preventing the full-scale adoption of agriculture and dynamic processes with external impacts that enable innovative transformation (Amkreutz, 2013; Cappers & Raemaekers, 2008; Elliott et al., 2020; Louwe Kooijmans, 1993; Madsen, 1986; Out, 2009; Raemaekers, 1997, 1999; Tilley, 1996; Tringham, 2000).

Many studies prove a hiatus between these sections, which is based on a research-historical but also a conservation-related problem (Hartz, Heinrich, & Lübke, 2000; Hartz & Lübke, 2006; Meiklejohn, Marcel, & Plicht, 2015; Müller et al., 2010; Niekus, 2005/2006). Based on the absolute chronological data, a gap between Swifterbant and Funnelbeaker period could be assumed. Further questions and research fields can be raised based on this dataset. With this contribution, we attempt to generate a chronological Bayesian model. The aim is to compare the numerous available radiocarbon data in one overview. In practical terms, we want the study to cover the following points:

1. What are the approximate transitions of the Swifterbant phases and the Funnelbeaker period according to absolute data in this study area?

2. What are the differences between the traditional chronology scheme and the chronological Bayesian model?
3. What are the outlook and possibilities for future models?

## 2 Materials and Methods

### 2.1 Materials and Data

In archaeology, absolute dating is an indispensable basis for understanding the development and dynamics of cultural phenomena. For evaluations that go beyond the inner-local level, the collection of data in large numbers is indispensable. Even modern statistical analyses, such as sequential calibration based on Bayesian methods, do not require individual data, but a large number. By combining large amounts of data, far more differentiated results can be obtained than by using conventional analyses (Hinz et al., 2012; Müller, 2004; Whittle, Healy, & Bayliss, 2011).

A data set (A1) was selected from the material of the study area described above. The dates used for the analysis originate from the database Radon (Baales et al., 2013; Hinz et al., 2012; Lanting & Plicht, 1999/2000; Menne, 2018; Mennenga, 2017; Raemaekers, 2011a, 2011b, 2011c; Raemaekers, 2003/2004). In a first important step, we reviewed critically the 182 samples out of 83 contexts to determine the quality and reliability of the sample contexts from the Swifterbant to Funnelbeaker Westgroup period (Figure 1 and Figure A1). We attempted to minimize this source of error by repeatedly matching the data in the original literature. Only data from a secure archaeological context and without reservoir effect were considered. Often different information on the different dates was available, which in part also led to potential sources of error. The aim of this dataset is to provide a reliable data basis.

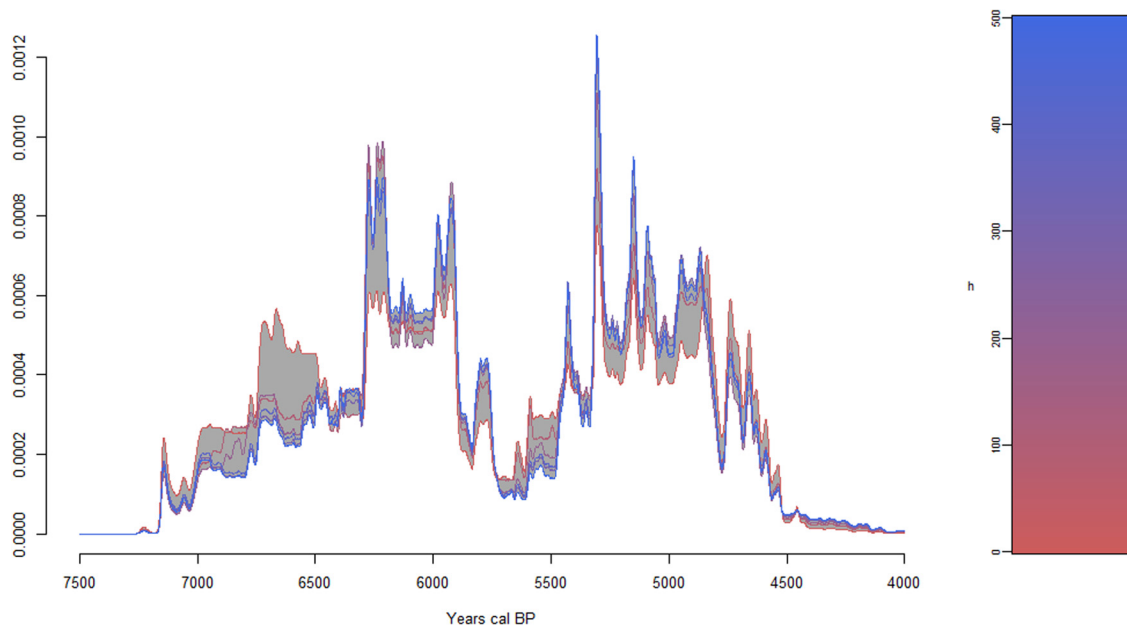
The codes and data are written in the statistical programming language R (R Core Team) and the Chronological Query Language (CQL2) and they are fully reproducible. They are available in a public repository on Open Science Framework with a permanent digital object identifier (DOI) <http://dx.doi.org/10.17605/OSF.IO/WC8YA>.

### 2.2 Analytical Method

In a first analysis, all dates were analyzed using a summed probability distribution with the R-package “rcarbon” (Bevan et al., 2020). The “rcarbon” is an R-package for the analysis of large collections of radiocarbon data, with special emphasis on the “date as data” approach developed by Rick (1987). It provides basic calibration functions as well as a set of statistical tests to examine aggregated calibrated data, commonly referred to as summed probability distributions of radiocarbon data (SPDs or SPDRDs).

Afterward, the dates were subdivided according to their assignment to Early, Middle, Late, or Funnelbeaker Westgroup (FBW) (A1). Based on this assignment to the appropriate group, KDE models of each phase were analyzed in OxCal 4.4. The KDE\_Model algorithm in OxCal can be tested against the same simulated, evenly distributed data as used in the sum method (Bronk Ramsey, 2017). The algorithm removes high-frequency noise in the form of sharp edges, peaks, and valleys, but retains the signal in the lower frequency range. The KDE\_Model has been implemented in OxCal; the kernel and factor have been set to N(0,1) and U(0,1) by default, as in the KDE\_Plot function above (Bronk Ramsey, 2017).

As the last step, we adopted a Bayesian modeling approach, which is applied here to the region, using the program OxCal 4.4 (Bronk Ramsey, 2009a; Buck, William, & Litton, 1996) and the Intcal20 curve (Reimer et al., 2020). Usually, radiocarbon dates are converted to calendar ages, which are given as confidence intervals (Bronk Ramsey, 1997). More than one radiocarbon age corresponds to a given calendar date, resulting in slightly larger overall confidence intervals. Attempts to reduce these intervals must be addressed quantitatively. The Bayesian analysis is a useful tool to address such problems and can determine confidence intervals and probability



**Figure 2:** Normalized SPD of 182 radiocarbon dates from Swifterbant to Funnelbeaker of the Netherlands and Northwest Germany (Appendix 1).

distributions for the calibrated radiocarbon data. More than two decades ago Bayesian method was adopted in archaeological applications (Buck, Kenworthy, Litton, & Smith, 1991; Buck, Litton, & Smith, 1992, 1994; Buck et al., 1996; Christen, 1994; Christen, Clymo, & Litton, 1995; Christen & Litton, 1995).

To determine the functional form of the probability function, it is usually assumed that the observations belong to a given interval (time scale). By specifying how probable the data are within the interval, a probability distribution function is obtained for the data. In OxCal 4.4, one can use different “boundaries” to define the type of probability distribution used (Bronk Ramsey, 2009a). During the analysis, each posterior distribution gets a match index ( $A$ ), which is shown on the OxCal plot.  $A$  indicates the extent to which the final (posterior) distribution overlaps with the original distribution. An unchanged distribution has an  $A$ -index of 100%, but the value may be higher if the final distribution only overlaps with the very highest part of the previous distribution. If the  $A$ -value for a single position is less than 60%, it may be necessary to question its position in that period, generating an error message (this degree of disagreement is very similar to the Chi-square test at the 5% level). For a group of items (such as a sequence), it is possible to define an overall agreement index, which is a function of all the indices within the group. If this falls below 60%, it may be necessary to reassess the assumptions made. This overall agreement is shown (Figure 4) at the top of the sample group and is presented in a form as follows: sequence  $\{A = 100.9\%$  ( $A'c = 60.0\%$ ) $\}$ , where  $A$  is the calculated index of overall agreement and  $A'c$  is the level below which it is unlikely to fall (Bronk Ramsey, 2009a). To calculate the duration of each phase, we used a *Sequence-Phase* model in OxCal (Bronk Ramsey, 2009a). For separating the phases from each other, *Transition boundaries* were taken into the model. To visualize each phase within the model, *Kernel Density Plots* were integrated (Bronk Ramsey, 2017).

### 3 Results

In a first step, the 182 radiocarbon dates of Swifterbant as well as of Funnelbeaker Westgroup from the study area of the Netherlands and Northwest Germany with an SPD were analyzed (Figure 1 and Appendix 1<sup>1</sup>).

<sup>1</sup> All Appendices are available at <https://doi.org/10.1515/opar-2020-0191> and <https://osf.io/wc8ya/>.

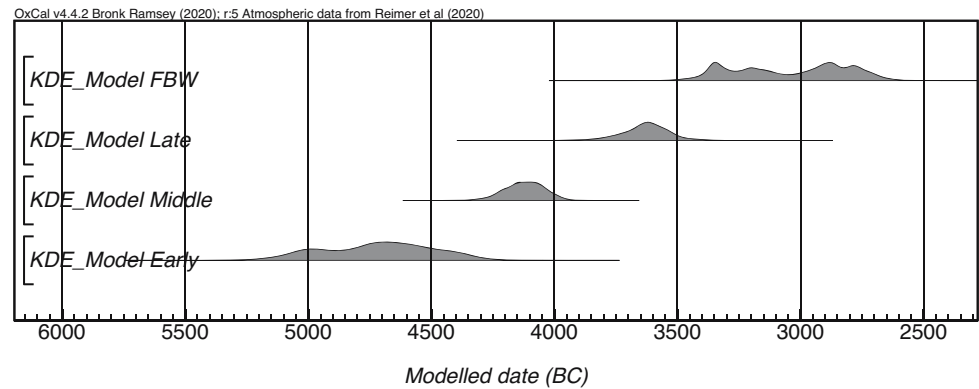


Figure 3: KDE models of the Early, Middle, and Late Swifterbant Phases and the Funnelbeaker Westgroup (Appendix 2).

Table 1: Absolute period and transition duration (Appendix 5)

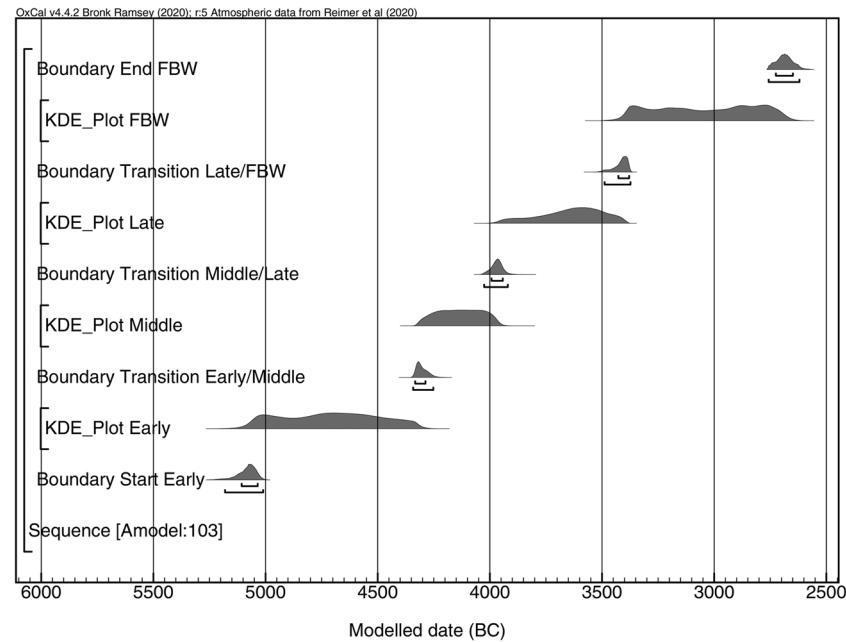
Period	cal BC 95.4%
Funnelbeaker Westgroup	3474–2640
Transition Late Swifterbant/Funnelbeaker	3489–3374
Late Swifterbant	3979–3395
Transition Middle/Late Swifterbant	4026–3921
Middle Swifterbant	4333–3943
Transition Early/Middle Swifterbant	4343–4253
Early Swifterbant	5134–4278

The result shows a data range from 7100 to 4500 cal BP. Two major peaks show up in the intervals between about 6250 and 5900 BP and between about 5250 and 4250 BP. A significant gap can be seen in the SPD between 5750 and 5300 BP (Figure 2).

In the second step, the individual radiocarbon dates were classified according to their context into the groups Early, Middle, and Late Swifterbant as well as Funnelbeaker Westgroup. To calculate the kernel density of each group, we used KDE models in OxCal 4.4. For the first group “Early Swifterbant” a total of 50 dates could be used for the model. This subgroup contains most of the radiocarbon dates for the Swifterbant phases. According to the calculated KDE model, the temporal range of this phase is between approximately 5210 and 4260 cal BC (95.4%). For the middle Swifterbant phase, 48 dates could be considered about the same number as for the early Swifterbant phase. Based on the KDE model, this time interval is significantly shorter than it was for the early phase, from about 4350 to 3950 cal BC (95.4%).

For the latest Swifterbant phase, only 15 dates were available. Nevertheless, these data show a chronologically distinct difference to the Middle Phase and dated from approximately 3920 to 3404 cal BC (95.4%). Already based on the KDE models in the two sigma range, a gap of approximately 30 years is to be assumed between the Middle and Late Swifterbant phase. The beginning of the Funnelbeaker Westgroup can be fixed around 3510 cal BC (95.4%). For this group, 71 dates could be used. The chronological end can be calculated around 2600 cal BC (95.4%). The KDE models of the groups considered show that they differ chronologically (Figure 3).

In order to calculate the time intervals of the transitions in a better way, we modeled in the last step the absolute dating of the different phases of the Swifterbant phenomenon with the Bayesian method. Therefore, we used a continuous phase model with transition boundaries in OxCal 4.4 (Figure 4). The data and group classifications used for the Bayesian model are the same as those used for the KDE models. Figure 4 shows the modeled duration for each of the four subdivisions, which has a high overall agreement. The model agreement is presented as an index to assess how well all measurements agree together within



**Figure 4:** Sequence Phase Model of all radiocarbon dates (Appendix 4).

the specified parameters. An acceptable model should display an Amodel value of no less than 60% (Bronk Ramsey, 2009b). The model for Swifterbant has an Amodel of 103%. The results of this model can be presented as follows (Table 1).

The model can be used to model not only the range of the individual phases but also the transitions to each phase (Figure 5). The transition from Early to Middle has to be defined between 4343 and 4253 cal BC (95.4%). From Middle to Late, the transition is at 4026–3921 cal BC (95.4%), and from Late to Funnelbeaker Westgroup, the period is between 3489 and 3374 cal BC (95.4%).

If the modeled phases are now considered, a slight overlap of at least 50 years can be seen from the Early to the Middle phase. At the transition from the Late Swifterbant phase to the Funnelbeaker Westgroup, even an overlap of a minimum of 80 years can be seen. Interestingly, this transition is the area where a gap would be expected according to traditional relative chronological models. In contrast, one could assume a gap between the Middle and Late Swifterbant phases. This is about 35 years in the 2-sigma range between the two modeled phases. Judging from the modeled transition, this span dates between 4026 and 3921 cal BC (95.4%).

## 4 Concluding Remarks and Outlook

The new modeled phases show remarkable differences in the traditional transitions of Swifterbant phases (Figure 6). The early phase is 200 years longer in this model. In particular, the middle phase of Swifterbant deviates from Raemaekers's definition (2003/2004, p. 29): it is much shorter and does not begin until around 4400 BC. In contrast, the late phase Swifterbant is confirmed very accurately by the model. The start of the Funnelbeaker Westgroup lies shortly after 3500 BC. Evidence of settlement processes between 3900 and 3400 BC in the northern Netherlands are still limited (Raemaekers, 2003/2004, 2013). The transition from the ceramic Mesolithic Swifterbant to the fully neolithic TRB is modelled between approximately 3500 and 3370 cal BC. After Raemaekers (2003/2004) "the late phase starts around 3900–3800 BC and ends with the start of the Funnelbeaker Westgroup around 3400–3300 BC" (see Lanting & Plicht, 1999/2000; Raemaekers, 2003/2004, p. 29). The model presented here shows the beginning of the TRB around 100 years earlier, also

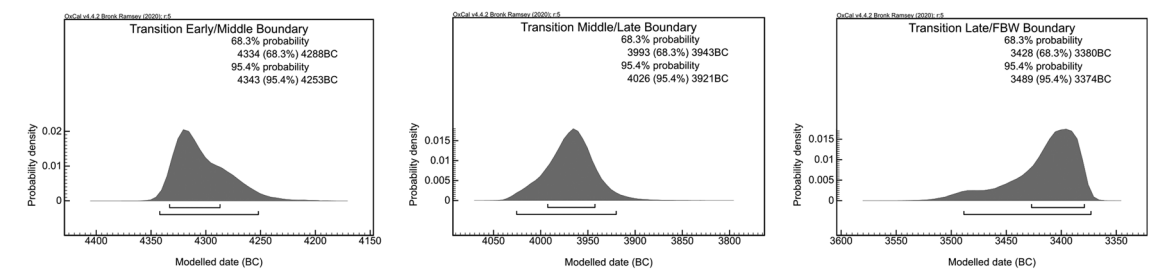


Figure 5: Transitions of the sequence phase model (Appendix 5).

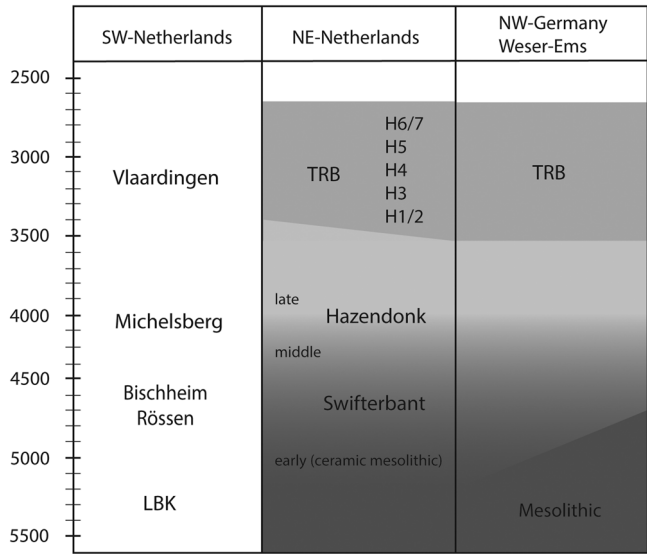


Figure 6: New schematic chronological table of Swifterbant and Funnelbeaker Westgroup development in Northwest Germany and Northeast Netherlands.

suggested by Mennenga (2017). Simultaneously, with the emergence of Funnelbeaker ceramics, the first megalithic structures are being built in the study area (Paulsson, 2019).

Traditional relative chronological concepts are often considering a hiatus between the Late Swifterbant phase to the beginning of the Funnelbeaker Westgroup. From the KDE model as well as from the Bayesian Analysis, there is more reason to assume a hiatus between Middle and Late Swifterbant than between Late Swifterbant and Funnelbeaker Westgroup. Unfortunately, there are only a few dates for the Late Swifterbant phase. This in turn could mean that the gap is mainly caused by the state of research and thus has to do with a lack of data. In the future, a broader dataset with stratigraphic classification of the finds is important for more detailed modeling. New data will help to see if the time periods we have modeled will be confirmed or shifted. Furthermore, it will be shown whether the gap between the middle phase and the late phase can be filled or whether it is actually a hiatus that has been seen so far rather between the late phase and the Funnelbeaker group.

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**Data availability statement:** The datasets generated and analysed during the current study are available in the Open Science Framework repository, <http://dx.doi.org/10.17605/OSF.IO/WC8YA>.

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